JOURNAL OF AGRICULTURAL RESEARCH
DEPARTMENT OF AGRICULTURE

VOL. VI WASHINGTON, D. C., JULY 10, 1916 NO. 15

STORAGE-ROTS OF ECONOMIC AROIDS

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INTRODUCTION [1]

The economic aroids within the scope of this article include various species and varieties of the genus Colocasia obtained from numerous warm regions throughout the world; a species of Alocasia received from Dutch Guiana under the varietal name "Eksi-taya" and *Xanthosoma sagittifolium* (L.) Schott, a native tropical American species. These plants are all of greater or less importance for human food in many tropical and subtropical countries, and they are being grown commercially or experimentally in the southern United States.

The Trinidad dasheen, a variety of taro, gives the greatest promise of success in the United States. It differs from many other taros in that it produces a considerable number of cormels, or "tubers," [2] of edible size, in addition to the large, edible, central corm. There are a number of varieties resembling it more or less closely. China is believed to have been the original home of the Trinidad dasheen, which is referred to *Colocasia esculenta* (L.) Schott.

Another group of taros, resembling the Trinidad dasheen in general leaf and floral characters and in the production of a large number of tubers, is represented by the Yu-to variety, from Mukden, Manchuria. Several of the Japanese taros, or "imos," are similar to this variety. The tubers are often very numerous, but usually quite small. These varieties are at present also referred to *C. esculenta*.

The Egyptian taro, called "Qolqas," is a member of another group of taros probably belonging to *C. antiquorum* (L.) Schott. A variety of this type, obtained by the Department from Cat Island, S. C., in 1906, is representative of this group. This group is distinguished from the

[1] The first four paragraphs of the introduction were prepared by Mr. R. A. Young, of the Office of Foreign Seed and Plant Introduction, Department of Agriculture.

[2] The word "tuber," the commercial term for "cormel" in the case of the dasheen, is used instead of "cormel" in this paper.

preceding by having a spathe that opens broadly, as well as by the general aspects of the plants. *C. indica* (Lour.) Kunth, a native of Java, was also used in these investigations.

The storage of dasheens by piling the tubers and corms in the field and overlaying them with straw and earth fully protects them against freezes and yields itself readily in other respects to a successful handling of the crop. In these piles, however, unless special means of ventilation are provided, many of the tubers and corms rot so badly as to render them useless for food or propagation. From such decayed material a considerable variety of organisms was isolated during the winter of 1912 and 1913. From similar material about the same organisms were isolated the following year. With these organisms inoculation experiments were made during the winter of 1913 and 1914, and repeated again in 1914 and 1915. Out of the different organisms isolated four were found to be wound parasites under certain conditions. Macroscopically it is not always easy to distinguish the different rots, since in some cases more than one of the rot-producing organisms may be present. An accurate diagnosis is also frequently obscured or rendered difficult by the invasion of saprophytic bacteria and fungi. Furthermore, the striking similarity of some of the rots in the earlier stages renders a diagnosis extremely difficult. While the writer can usually distinguish macroscopically typical cases of the several rots in the later stages, the only sure method is the preparation of cultures.

JAVA BLACKROT

The most common and destructive of the storage-rots is called the "Java blackrot" because of its resemblance to the Java blackrot of the sweet potato (*Ipomoea batatas*) caused by the same organism, *Diplodia tubericola*. The causal fungus has been isolated repeatedly during a period of three years from a number of varieties. This disease is particularly interesting in view of the fact that different species of the genus Diplodia obtained from other hosts widely separated botanically from the dasheen will cause a decay of the latter identical in character.

DESCRIPTION OF JAVA BLACKROT

The tissue when first invaded by the fungus is but little or not at all changed in color and is soft, slimy, and stringy. The substance of the corm or tuber becomes pasty and will, if picked up by the forceps, draw out in a threadlike manner. It is often difficult to distinguish the decay caused by the blackrot fungus in the early stages from the decay produced in the initial stages by other organisms without resorting to plate isolations. A little later, however, the tissue becomes slightly pinkish and then gradually turns black, and in this respect differs from the decayed tissue produced by the other organisms. At the same time the rotted portion of the tuber gradually becomes firmer by the escape of moisture.

Plate LXXXI, figures 1 and 2, shows the typical rots of *C. esculenta* and *Alocasia* sp., respectively, produced by the Java blackrot fungus.

The rot progresses slowly. About seven days elapse after inoculation before any noticeable softening of the tuber occurs under optimum conditions and about four to eight weeks are required for complete destruction of the tuber and blackening of the tissue. Finally both the tubers and corms become very dry and hard and are cut by a knife with difficulty. The middle lamella is first dissolved, the hyphæ later penetrating the cell walls and burying themselves among the starch grains. The tissue finally becomes a disorganized mass and powdery when completely dried. Under normal conditions the rot does not produce any, or, at most, only slight shrinking or malformation of the tuber. In fact, a whole tuber may be completely destroyed internally and become black throughout without much external evidence of it. Fruiting bodies later develop, but they are mostly covered by the epidermis and can scarcely be detected without rupturing the surface.

Under natural conditions the corms decay more readily than the tubers, although the latter are frequently met with in storage and succumb easily to artificial inoculation. It is evident from a careful study of material that natural infection originates in the wounds made by breaking the tubers from the corms and at points where the roots are broken off. After becoming established the fungus may spread in all directions without penetrating deeply until the surface of the corm is well covered, and then it may penetrate farther in; or it may cover an area 1 or 2 inches in diameter and push inward to the center in the form of a cylinder.

CAUSE OF BLACKROT

The writer has isolated and successfully inoculated into the dasheen species of Diplodia from five different hosts, as follows: *D. tubericola* (E. and E.) Taub. from sweet potato; *D. gossypina* Cke. from a dead limb of cotton; *D. maclurae* Speg. from a dead branch of *Toxylon pomiferum* Raf. from New Jersey; *Diplodia* sp. from a limb of *Mangifera indica* from Cuba, furnished by Dr. J. R. Johnston, pathologist of the Cuban Experiment Station, and a species of Diplodia from dasheen which, because of its great similarity to *D. tubericola*, is referred to that species. The type of decay produced by these different species is macroscopically the same. It is a well-known fact that there are a great number of different species of Diplodia described in the literature, many of which may prove to be identical. No attempt has been made to go into the taxonomy of this group, but it may be of interest to note the points of similarity and difference between the species here studied. The organism isolated from dasheen can not be distinguished in culture from *D. tubericola* from sweet potato. Both develop into stroma in culture and on the host, and the spores differ but little in shape (fig. 1, *A*, *B*) and size.

D. gossypina has been shown by Edgerton (3) to be primarily a wound parasite of cotton bolls and by Taubenhaus (9) [1] to produce a

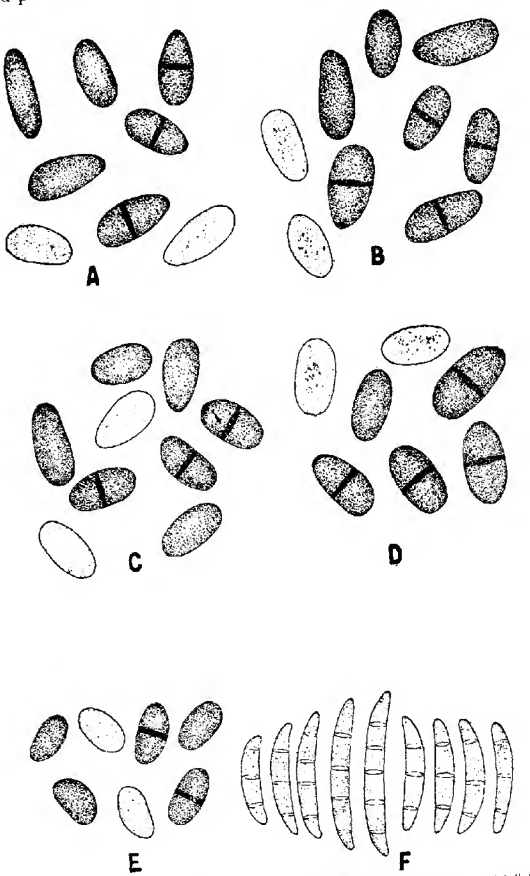

FIG. 1.—Spores of different storage-rot organisms: *A*, *Diplodia tubericola* from dasheen; *B*, *Diplodia tubericola* from sweet potato; *C*, *Diplodia gossypina* from cotton; *D*, *Diplodia* sp. from *Mangifera indica*; *E*, *Diplodia macdanielii* from *Toxylon pomiferum*; *F*, *Fusarium solani*. × 500.

typical Java blackrot of sweet potatoes. The writer found the fungus produced a decay of dasheens identical with that caused by *D. tuberi-*

[1] Reference is made by number to "Literature cited," p. 571.

cola from sweet potatoes and from dasheens and to agree closely in cultural characteristics and in shape (fig. 1, *C*) and size of spores. While *Diplodia* sp. from *Mangifera indica* and *D. maclurae* both produce a typical rot of dasheens and agree with the other species in cultural characteristics and shape of the spores (fig. 1, *D*, *E*), the spores of the latter fungus are uniformly smaller in size. *D. maclurae* is less virulent for dasheens than the other species. The spores from the host of the different species studied measure as follows:

Diplodia tubericola from sweet potato, 22.3 to 34.4 by 10.3 to 13.7μ. Average, 11.6 by 25.5μ (30 measurements).

Diplodia tubericola from dasheen, 22 to 33 by 10.3 to 13.7μ. Average, 11.3 by 26.5μ (30 measurements).

Diplodia gossypina from cotton, 20.1 to 28 by 9 to 13.4μ. Average, 11.5 by 24.5μ (31 measurements).

Diplodia maclurae from *Toxylon pomiferum*, 17.5 to 22.3 by 8.5 to 11μ. Average, 9.7 by 19.7μ (30 measurements).

Diplodia sp. from *Mangifera indica*, 23 to 31.6 by 12 to 14.1μ. Average, 13 by 26.2μ (31 measurements).

In 1906 Charles (2) isolated and studied a species of Lasiodiplodia from the fruit of *Mangifera indica*, but left the question unsettled as to whether it was the same organism found on the sweet potato. However, the results obtained by the writer by inoculation studies with the above species and by Taubenhaus (9), who obtained positive infections of sweet potatoes with several species of Diplodia, suggest the possible identity of many of these forms described as different species. The results also indicate that these crops are exposed to infection from several sources.

INOCULATION EXPERIMENTS

INOCULATION OF COLOCASIA ESCULENTA

On January 6, 1914, thirteen dasheen tubers, after being thoroughly washed and disinfected for 10 minutes in mercuric chlorid (1:1,000) and rinsed in water, were inoculated in a wound at the end by inserting spores and hyphæ of *D. tubericola* from dasheen. All inoculations were made from cultures grown on cooked potato cylinders in which spores were present, although in many cases they were hyalin and nonseptate. After inoculation the tubers were placed in a large, uncovered, moist chamber and subjected to the temperature and humidity of the laboratory room. By January 19 the rot had noticeably started on all the tubers, and by January 28 all were completely decayed. The causal organism was recovered in pure culture from each tuber. The checks, six in number, similarly located remained healthy.

On the same date seven tubers prepared as above and inoculated with the same organism were placed in a covered moist chamber with wet filter paper in the bottom and placed on a shelf in the laboratory. These

tubers were kept under observation until February 17, and none showed any evidence of decay. The checks, two in number, under similar conditions but not inoculated, remained healthy. This and subsequent experiments showed that better results could be obtained by merely exposing the inoculated tubers to the surroundings of the laboratory room. The use of moist chambers, therefore, was abandoned, with the exception of an occasional trial experiment to be noted later. Disinfection likewise was no longer practiced, since the tubers were immediately exposed to reinfection from the air of the room. Although the rot caused by *D. tubericola* is very easily recognized and characteristic when once known, cultures were made from nearly all the decayed tubers, in order to be sure the rot was caused by the used organism. The influence of temperature and moisture on these storage rots will be discussed later.

On January 16, 1914, four tubers were inoculated in the usual way with *D. tubericola* from dasheen. By February 18 all were rotted and the causal organism recovered in pure culture. The checks, two in number, remained healthy.

On March 1, 1914, twelve tubers were inoculated with *D. tubericola* from dasheen. On March 12 several tubers showed evidence of decay and by March 20 nine were partially rotted. A portion of some of the tubers was black, and pycnidia containing hyalin 1-celled spores were present. On June 1 all the tubers were completely decayed. The checks, five in number, remained sound.

On January 14, 1915, four tubers were inoculated with *D. tubericola* from sweet potato. On February 18 all the tubers were rotted, and the causal organism was recovered in pure culture. Two days later ten tubers were inoculated and divided into two equal lots, one being placed in an incubator, the temperature of which varied from 34° to 35° C., and the other in an ice box, the temperature of which varied from 12° to 13°. By February 3 all the tubers in the incubator were rotted and the causal organism was recovered in pure culture, while those in the ice box and the five checks remained sound.

On March 26 six tubers were inoculated with *D. maclurae*. Some time later one was completely decayed and yielded *D. maclurae* in culture; the others remained sound. Four more tubers were inoculated on May 13, 1915, and on June 6 three tubers were half-decayed, *D. maclurae* being recovered from two, *Rhizopus nigricans* from one, and *Fusarium* sp. from one. The checks, five in number, remained sound.

Six other tubers were inoculated on May 20, 1915. On June 1 two were completely decayed and four remained sound.

On December 23, 1914, nine tubers were inoculated with *D. gossypina*, five of which were placed in an open receptacle on the laboratory shelf and four in a moist chamber. All the exposed tubers were rotted on

January 13, and *D. gossypina* was recovered. In the moist chamber two tubers were sound; the other two rotted a very little, one of which yielded *Fusarium solani* and the other *F. oxysporum*. Out of six other tubers inoculated on March 1 five were completely rotted on March 26. The checks, five in all, remained sound.

On January 29, 1915, ten tubers were inoculated with *Diplodia* sp. from *Mangifera indica*. Nine of these tubers showed evidence of rot on February 8; and on February 20 six were completely decayed, three were half-decayed, and one remained sound. The checks, five in number, remained sound.

INOCULATIONS OF XANTHOSOMA SAGITTIFOLIUM

On November 30, 1914, five tubers were inoculated with *Diplodia tubericola* from dasheen and five with the same organism from sweet potato. On December 23 all the tubers in both lots were rotted and the causal organism was recovered in pure culture. The checks, five in number, remained sound. Six other tubers were inoculated on December 9 with the sweet-potato organism, and on January 2, 1915, *D. tubericola* was recovered from four and *Fusarium oxysporum* from two.

On January 4, 1915, ten tubers were inoculated with *D. maclurae* and five with *D. gossypina*. By February 10 five of the former and three of the latter were decayed and the causal organisms recovered. The five checks remained sound.

INOCULATION OF COLOCASIA INDICA

On December 9, 1914, four tubers were inoculated with *D. tubericola* from dasheen and five with the same organism from sweet potato. All the tubers in both lots were completely decayed on January 2, 1915, and the causal organism was recovered. The checks, four in number, remained sound.

INOCULATION OF ALOCASIA SP.

Five tubers were inoculated on January 2 with *D. tubericola* from dasheen, and on February 10 three were decayed. *D. tubericola* was recovered from two and *Fusarium* sp. from one. The two others and the five checks remained sound. On the same day five tubers were inoculated with the same organism from sweet potato, and on February 10 one tuber was sound. The four others were only partially decayed, but *D. tubericola* was recovered from the rotted portion. It appears that, while this species is not wholly immune to the rot, it is more resistant than the others. On January 4, 1915, four tubers were inoculated with *D. maclurae* and four with *D. gossypina*. All those inoculated with *D. maclurae* remained sound, but of those inoculated with *D. gossypina* two were completely decayed and two one-third rotted. The causal organism was recovered from each.

Table I gives the results of these inoculation experiments with *Diplodia* spp.

TABLE I.—*Results of the inoculations of tubers of Colocasia esculenta, Xanthosoma sagittifolium, C. indica, and Alocasia sp. with Diplodia tubericola, D. macluræ, D. gossypina, and Diplodia sp. from Mangifera indica*

Organism.	*Colocasia esculenta.*			*Xanthosoma sagittifolium.*			*Colocasia indica.*			*Alocasia* sp.		
	Inoculated.	Infected.	Checks.	Inoculated.	Infected.	Checks.	Inoculated.	Infected.	Checks.	Inoculated.	Infected.	Checks.
D. tubericola from dasheen	36	29	[a]13	5	5	[a]5	4	4	[a]4	5	5	[a]5
D. tubericola from sweet potato	14	9	5	11	9	5	5	5	4	5	4	....
D. macluræ	10	4	5	10	5	5	....	....	....	4	0	....
D. gossypina	15	10	5	5	3	5	....	....	....	4	4	....
Diplodia sp. from *Mangifera indica*	10	9	5	....	....	....	....	....	....	....	....	....

[a] None of the checks became infected.

POWDERY GRAYROT

Since this form of storage-rot has never been reported before, the writer proposes that it be known by the name "powdery grayrot." This, like many other common names of plant diseases, is somewhat misleading, since the rot in its early stages is soft and, if invaded by bacteria, is slimy on the surface. In the later stages, however, it becomes powdery and gray, this appearance serving to distinguish it from the other storage-rots.

DESCRIPTION OF POWDERY GRAYROT

This rot has been isolated repeatedly from tubers and corms from Brooksville, Fla., and from specimens imported from Japan in May, 1915. Infection usually begins in the wounds made by breaking the tubers and corms apart, showing that it is probably strictly a wound parasite. When infected at such a point, the rot may spread rather widely over the surface, penetrating only half an inch or so; or it may penetrate under a small area to the center of the tuber or corm, though the number of specimens having been seen completely decayed by this organism is relatively small. In the final stages this rot becomes rather hard, dry, and powdery and is of a grayish color and crumbles when cut with a knife.

Numerous inoculation experiments have made it possible to study the progress of this rot more in detail in the laboratory. The first evidence of decay appears in 24 hours after inoculation on a cut surface, manifested by the formation of an ocherous to salmon-orange color. This color

becomes gradually darker and eventually turns brown, particularly just below the surface. Softening accompanied by stringiness of the tissue begins in 48 hours and extends to a depth of ¼ to ½ inch in one week. After a week or 10 days the surface becomes somewhat slimy and glistening from the production of pionnotes composed of numerous typical spores of the causal fungus. Upon drying, the specimen takes on a putty-like texture, shrinks perceptibly, and finally becomes dry and powdery and of a dark-grayish color. Plate LXXXII, figures 1 and 2, shows typical specimens of *Colocasia esculenta* and *Xanthosoma sagittifolium*, respectively, partially decayed by the powdery-grayrot fungus.

An examination of rotted material shows that the fungus first destroys the middle lamella and later to some extent invades the cells themselves, the tissue finally becoming a disorganized mass of separated cells.

CAUSE OF POWDERY GRAYROT

For a period of three years *Fusarium solani* (Mart.) Sacc. has been repeatedly isolated in pure culture from decayed tubers and corms and has reproduced the characteristic rot when inoculated into dasheens. From such inoculated tubers the organism has been recovered and again made to produce the disease and subsequently recovered. The causal organism has been found to agree with *F. solani* as laid down by Appel and Wollenweber (1) both culturally and in size and septation (fig. 1, *F*) of spores, as shown by the following measurements: Tri-septate conidia taken from pionnotes of a 16-day-old culture on cooked Irish potato vary from 27 to 41 by 5.0 to 6.2μ and average 5.7 by 37.0μ. Four-septate conidia, 34.4 to 51.6 by 5.2 to 6.2μ, average 5.7 by 41.6μ. Five-septate conidia, 5.4 to 5.9 by 41.3 to 51.6μ, average 5.6 by 47.4μ. In this connection it should be stated also that *F. solani* from Irish potato, isolated and identified by Wollenweber at Dahlem, near Berlin, Germany, produced a similar rot of dasheens. No difference between the two organisms could be detected either culturally or in their parasitic habits.

INOCULATION EXPERIMENTS

A few preliminary experiments demonstrated that no decay would result when this fungus was spread on an unbroken surface. On the other hand, if placed on a freshly wounded surface, decay started in 24 to 48 hours, provided sufficient moisture was present to enable the fungus to get a start. These results seem to indicate that the fungus gains access to the tubers through wounds made by separating the tubers and corms or through wounds made by other means. The results of our experiments showed that two reliable methods of inoculation could be trusted; (1) Inoculation of the tuber by wounds made by pricking with a sterile needle or scalpel or (2) by splitting a corm or tuber in two and smearing spores on the cut surface. If the latter method was employed, a

film of water, such as may be supplied by a fine spray from an atomizer, must be provided for one or two days, after which the rot will continue independently. That *F. solani* smeared on a moist cut surface of dasheen develops as a wound parasite and not a saprophyte is evident from the fact that other fungi, such as *F. oxysporum* Schlecht., and *F. caudatum* Wollenw. isolated from dasheen, when similarly used produced no decay.

INOCULATION OF COLOCASIA ESCULENTA FROM TRINIDAD

On January 21, 1915, six tubers were inoculated in a moist chamber by smearing spores of *F. solani* from dasheen on the cut surface. A soft-rot started in two days and by January 27 it had penetrated half an inch. The causal fungus was recovered from each. The checks, six in number, remained sound. On January 24, six tubers were inoculated and by February 11 all were completely decayed and *F. solani* was recovered from five. The plate in which the other planting was made was overrun with a species of Rhizopus. The checks, six in number, were sound. Six tubers inoculated on February 6 were completely rotted in 9 days. Six inoculations made on March 1, 1915, in the usual way were all rotted on March 9. No isolations were made. The checks, four in all, remained sound. On March 6 four tubers were inoculated into a cut surface at the end of the tuber and two on an unbroken surface at the side. Those inoculated into a wound rotted freely; the others remained sound.

On February 16 six tubers were inoculated with *F. solani* from Irish potato, and in nine days the tubers were well decayed, the rot being identical with that produced by tubers inoculated with the same organism from dasheen. The checks, six in all, remained sound. On March 1 six tubers were inoculated with *F. solani* from Irish potato, and in nine days all the tubers were mostly but not completely rotted. The four checks remained sound.

INOCULATIONS OF COLOCASIA ESCULENTA FROM MANCHURIA

This is a variety of taro from Manchuria with small tubers about 2 inches long and 1 inch in diameter. On March 1 twelve of these tubers were inoculated with *F. solani* from dasheen. In seven days all the tubers were completely decayed, and the causal organism recovered from each. The checks, six in number, remained sound. An examination of the decayed specimens showed that, while the middle lamella was largely destroyed, the fungus did not to any extent invade the cells.

INOCULATIONS OF XANTHOSOMA SAGITTIFOLIUM

On March 1 six tubers were inoculated with *F. solani* from dasheen, and in seven days the tubers were well decayed but not completely, the rot being identical with the rot of *Colocasia esculenta* produced by the same organism. *F. solani* was recovered from each tuber in pure culture. The checks, four in number, remained sound.

The results of these inoculation experiments with *F. solani* are given in Table II.

TABLE II.—*Result of the inoculations of Colocasia esculenta (Trinidad), C. esculenta (Manchuria), and Xanthosoma sagittifolium with Fusarium solani*

Colocasia esculenta (Trinidad).			*Colocasia esculenta* (Manchuria).			*Xanthosoma sagittifolium.*		
Inoculated.	Infected.	Checks.	Inoculated.	Infected.	Checks.	Inoculated.	Infected.	Checks.
[a]42	39	[b]26	12	12	[b]6	6	6	[b]4

[a] Twelve tubers were inoculated with *F. solani* from Irish potato; all others with *F. solani* from dasheen.
[b] None of the checks became infected.

SCLEROTIUM-ROT

The sclerotium-rot, while common in the storage heaps where high temperatures and a relatively high humidity prevails, is not so frequently met with under all circumstances as rots caused by *F. solani* and *D. tubericola*. The causal fungus is known to occur on a number of hosts widely separated in relationship, such as tomato (*Lycopersicon esculentum*), peanut (*Arachis hypogaea*), cabbage (*Brassica oleracea*), cotton (*Gossypium* spp.), violet (*Viola* spp.), and others. It has been found growing on the dead scales and other débris of many dasheen plants in the field in Florida, but not a single sure case has been found where it invaded the sound tissue. It, like the other fungi so far discussed, is primarily important only as a storage-rot.

DESCRIPTION OF SCLEROTIUM-ROT

During a period of three years many tubers and corms have been examined which were somewhat mushy and watery and often covered by numerous almost spherical sclerotial bodies. The watery putrid condition often accompanying this decay is usually the result of saprophytic fungi and bacteria which followed the progress of the Sclerotium fungus. If this putrid substance is pared away, a firmer (Pl. LXXXI, fig. 3), almost odorless decay will be found from which a pure culture of the causal organism can be plated out. The rotted tissue is ocherous to brown in color, soft but not watery, with a tendency to stringiness. A sharp line characterized by a difference in color separates the healthy from the diseased tissue. The destruction of the tissue is apparently brought about by an enzym secreted by the fungus. At least there is a soft zone ¼ to ½ inch in width with the charactistic color of the rot from which the organism can not be isolated.

The hyphæ do not enter the cells to any extent, but the tissue finally becomes badly disorganized through the destruction of the middle lamella.

CAUSE OF SCLEROTIUM-ROT

The sclerotium-rot is caused by *Sclerotium rolfsii* Sacc., a fungus which was first mentioned by Rolfs (6, p. 31) in 1893 and technically described by Saccardo (7, p. 257) in 1911.

In about seven days after inoculation in a moist chamber the sclerotial bodies begin forming. They are almost spherical, at first white, but later becoming brown, and finally nearly black, with a hard, shiny surface. This organism, the sclerotial bodies of which are composed of solid masses of fungus tissue, is, according to Wolf (10), parasitic on peanuts and a number of other legumes.

INOCULATION EXPERIMENTS

All inoculations were made in moist chambers and kept in the laboratory except those in which temperature relations were studied, the results of which are discussed later. All attempts to produce the rot by placing bits of hyphæ on an unbroken surface of the tuber were unsuccessful. It was later found, however, that when the inoculations were made on a cut surface or in a small wound made by a scalpel they were uniformly successful if sufficient moisture was provided at the outset. Moisture was consequently furnished by spraying once or twice with water from an atomizer, and after 24 to 48 hours further applications of water were unnecessary. The fungus grows very rapidly and in a few days covers the whole surface of a tuber (Pl. LXXXII, fig. 3) split in two and even spreads onto the unwounded surface, although the scales of these aroids appear to be impenetrable by the fungus. Within a week the tissue is softened for half an inch or more, although under favorable conditions a month is often required to decay completely a tuber.

INOCULATION OF COLOCASIA ESCULENTA

On January 14, 1915, six tubers of the Trinidad dasheen were inoculated with *S. rolfsii* by placing bits of hyphæ on a cut surface. Decay started in 2 days, and in 13 days the hyphæ had overrun the whole cut surface of the tuber and softened the tissue to the depth of half an inch. The checks, six in number, remained sound. On January 27 six tubers were inoculated, and by February 9 the tubers were well rotted and sclerotia forming. The checks, four in number, remained sound. On February 2 sixteen tubers were inoculated, and in 13 days all were softrotted and covered with a dense growth of hyphæ. The checks, five in all, remained sound. On February 6 four tubers were inoculated on an unbroken surface, but no growth had taken place by February 23, and they were thrown out. No checks. On February 15 eight tubers were inoculated and in 8 days they were all soft rotted, with sclerotia developing abundantly. Two tubers were inoculated on March 6 at the end in a small wound made by a scalpel and were well rotted by March 15.

INOCULATION OF XANTHOSOMA SAGITTIFOLIUM

On January 25 sixteen inoculations were made by placing bits of hyphæ on the cut surface and in 12 days all were softrotted and sclerotia abundantly produced. The six checks remained sound.

The results of the inoculation experiments with *S. rolfsii* are given in Table III.

TABLE III.—*Results of inoculation experiments with Sclerotium rolfsii*

Host.	Date of inoculation.	Inoculated.	Infected.	Checks.	Checks infected.
Colocasia esculenta	Jan. 14	6	6	6	0
Do	Jan. 27	6	6	4	0
Do	Feb. 2	16	16	5	0
Do	Feb. 6	4	0	0	0
Do	Feb. 15	8	8	0	0
Do	Mar. 6	2	2	0	0
Xanthosoma sagittifolium	Jan. 25	16	16	6	0

SOFTROT

Many tubers have been examined which were softrotted and emitted a very disagreeable, repellent odor. At first the odor was supposed to be produced by saprophytic bacteria following the invasion of the host by some one of the organisms already discussed. From many such specimens, however, after paring away most of the rotted material, no fungi could be isolated. Microscopic examination of such material disclosed very actively motile bacteria which were readily isolated by the poured-plate method.

This is the only disease of the four studied which occurs to some extent in the field, mostly in the lower and poorly drained parts. Plate LXXXIII shows a corm and leaf attached as it appeared when lifted in the field. The lower part of the corm is decayed away. The organism isolated from this corm was used in some of the inoculation experiments which follow. The organism was also isolated from tubers and corms in the storage piles and once from the dark strands running through the corms. These strands sometimes appeared darker than normal, and microscopic examinations indicated invasion by some organism, but repeated attempts to isolate one failed until the winter of 1915, when a bacterium was isolated from a diseased strand in the center of a big corm by macerating bits of the decayed tissue in a tube of sterile water and pouring agar plates in the customary way. Numerous colonies later developed which proved to be identical with that produced by the other strains isolated from rotted tissue and to produce a rot similar to it. Usually these strands can be traced to the exterior of the corm, showing that the invading organism probably followed the strand. Under suit-

able conditions decay sets in which eventually results in the partial or complete destruction of the corm.

DESCRIPTION OF SOFTROT

Softrot is characterized by being watery and slimy, with a disagreeable, repellent odor. The tissue is little or not at all changed in color under natural conditions. Under sterile, artificial conditions the surface becomes slightly reddish brown. Sections through diseased tissue show that the middle lamella is dissolved and the intercellular spaces are filled with bacteria. The cells themselves are seldom, if ever, invaded.

CAUSE OF SOFTROT

The softrot of dasheen is caused by the well-known softrot organism of many vegetables, *Bacillus carotovorus* Jones. This conclusion was arrived at by a comparison in culture of the growth of the organism from dasheen with an authentic culture of *B. carotovorus* kindly furnished by Dr. L. R. Jones, of the University of Wisconsin, and by a series of cross-inoculations.

The comparison of growth of *B. carotovorus* on different culture media was made with three strains from dasheen as follows:

3624. *Bacillus carotovorus* Jones (furnished by Dr. Jones).
3595. A strain isolated from a partially softrotted Trinidad dasheen.
3616. A strain isolated from a Pat-long-fu taro (*C. esculenta*). (See Plate LXXXIII.)
3626. A strain isolated from the fibrovascular bundles at the center of a big corm of a Trinidad dasheen.

All these strains have produced the typical decay by inoculation. After rejuvenating the strains by transferring for several consecutive days to beef bouillon the following culture media were inoculated: Potato cylinders, milk, litmus milk, gelatin, nitrate solution, Cohn's solution, Dunham solution, Uschinsky's solution, beef bouillon, beef-agar slants, beef-agar plates and saccharose, lactose, dextrose, and glycerin bouillon in fermentation tubes. None of the strains grew in Cohn's solution. Gelatin was promptly liquefied by all strains, and nitrates were changed to nitrites when tested according to the method recommended by Smith (8).

Strain 3624 gave a prompt test for indol upon the addition of sulphuric acid and sodium nitrate, white strain 3595 yielded but a faint pink at first, which intensified upon warming to 75° C. The other two strains were doubtful. Strain 3624 was a slower grower than the others on practically all media as well as the less vigorous parasite, but the difference between the growths of this strain on the various media was no greater than the difference between the growths of the different strains from dasheens, or between the growths in different tubes of the

same strain. The one striking exception to the above statement may be noted in connection with the results obtained with saccharose, lactose, dextrose, and glycerin broth in fermentation tubes. Strain 3624 produced gas (a small amount) in all, while none of the other strains did. Such a difference, however, is not surprising in view of the fact that Harding and Morse (4) found that of the various strains from different sources studied by them some consistently failed to produce gas.

The writer wishes to emphasize in this connection that he has carefully compared his results with the studies of Jones (5) and Harding and Morse (4) and has frequently consulted Smith's "Bacteria in Relation to Plant Diseases" (8) for methods. Slight differences in cultural characteristics have been noted from time to time between the different strains, but these differences appear to be no greater than would naturally be expected between strains of the same organism. No attempt has been made to duplicate all the work of Jones or of Harding and Morse with this group of organisms, but merely to carry the work of comparison far enough to be reasonably sure that the writer was working with a strain similar to or identical with *B. carotovorus*.

By a series of cross-inoculations it was shown that the organism furnished by Dr. Jones would decay dasheens and the organisms from dasheens softrotted raw carrots and turnips. It should be emphasized in this connection that strain 3624 (Jones) was less virulent for dasheens than the strain isolated from dasheen, though it rotted carrots and turnips with ease.

INOCULATION EXPERIMENTS

As a preliminary test, 12 sterile raw blocks in test tubes with a little water added were cut from corms and inoculated on April 1, 1915, with a 24-hour-old culture (organism 3595) on beef bouillon. In three days there was evidence of decay in some of the tubes, and in 10 days four of the blocks were completely rotted. The checks, six in number, remained sound. The causal organism was recovered in pure culture from two of the blocks.

On April 19, 1915, twelve more sterile raw blocks and also six dasheen tubers in moist chambers were inoculated with a 3-day-old culture of beef bouillon by placing a loopful of the broth in a depression of a cut surface. The raw blocks in test tubes were all decayed by April 24. Four of the tubers in moist chambers were well rotted on the same date and the other two but slightly. The causal organism was reisolated from four. Six raw blocks in tubes and three tubers in moist chambers were held as checks. All remained sound. The lack of material prevented further work at this time. The work was again taken up in November, the tubers or corms being cut in two and inoculation made on the wounded surface in moist chambers, the surface being kept moist for

a day or two by spraying with sterile water from an atomizer. Cultures from beef bouillon were used for all inoculations.

On November 27 eight tubers were inoculated with organism 3616 from a 3-day-old culture and all were completely decayed in seven days. The organism was recovered from four. Strain 3616 was isolated from a Pat-long-fu taro (*Colocasia esculenta*) on November 18, 1915. The corm was decayed at the base and was lifted a few days before in the condition shown by Plate LXXXIII. Ten raw sterile blocks inoculated on the same day with each of strains 3595 and 3616 were completely decayed in three days. On November 24 ten tubers were inoculated with organism 3624 (*Bacillus carotovorus* from Dr. L. R. Jones) from a 24-hour-old culture. A slight rot had taken place in seven days; and in 12 days, although the decay had increased, it was still slight. The causal organism was recovered from three tubers. On December 1 eight tubers were inoculated with strain 3624, and in five days about half of each tuber was decayed. The organism was recovered from four. The checks, six in number, remained sound. On December 9 six raw carrot and six raw turnip blocks in test tubes were inoculated with strains 3616 and 3595. Decay started in 24 hours and was complete in five days. At the same time thirteen raw blocks of dasheens were inoculated with strain 3624 from a 2-day-old culture, and in 5 days nine blocks were completely decayed; the others and the ten checks remained sound. On December 13 three turnips and three carrots in moist chambers were inoculated with a 6-day-old culture of strain 3595, and by December 20 two turnips and one carrot were completely decayed. At the same time six dasheen tubers were inoculated with a 6-day-old culture of strain 3624. Decay began in 24 hours and in seven days had destroyed most of each tuber. The four checks remained sound. On December 20, 1915, four turnips and four carrots were inoculated with a 7-day-old culture of organism 3627 (a reisolation of 3616) and three turnips and four carrots with strain 3595. A rot started in 48 hours and decay was complete in seven days. The causal organism was recovered from the four turnips inoculated with strain 3627 and from the four carrots inoculated with strain 3595. The ten checks remained sound.

On December 27 four dasheens were inoculated with 1-day-old cultures of strain 3616 and six carrots and seven turnips with strain 3624. By January 3 the dasheens were nearly decayed and all the turnips and five of the carrots completely rotted. All the checks remained sound. Eleven turnips inoculated with 1-day-old cultures of strain 3616 were completely decayed by January 3, 1916. Four dasheen corms inoculated with 1-day-old culture of 3624 were but slightly rotted at the end of seven days. On December 28 three turnips and four carrots were inoculated with a 24-hour-old culture of organism 3626 (an isolation from a fibrovascular bundle at the center of a large corm). In six days

all but one turnip was nearly rotted. The four checks remained sound. On December 31 five turnips and five carrots were inoculated with a 48-hour-old culture of organism 3627. By January 9, 1916, three turnips and four carrots were badly rotted. The organism was recovered from all the decayed specimens. On January 6, 1916, four dasheen corms were inoculated with a 3-day-old culture of strain 3624. By January 13 a slight rot had taken place. The rot progressed but little in one more week and the specimens were thrown out. On January 7 six turnips and six carrots were inoculated with a 1-day-old culture of strain 3627 and by January 12 all were completely decayed. The causal organism was received from six. The seven checks remained sound.

Table IV gives the results of the inoculation experiments with *Bacillus carotovorus*.

TABLE IV.—*Results of inoculation experiments with Bacillus carotovorus*

Strain No.	Date of inoculation.	Host.			Inoculated.	Infected.	Checks.	Checks infected.	Reisolations.
		Dasheen.	Turnip.	Carrot.					
	1915.								
3595	Apr. 1	Raw blocks			12	4	6	0	2
3595	Apr. 19	do			12	12	6	0	0
3595	do	Tubers			6	4	3	0	0
3595	Nov. 27	Raw blocks			10	10	0	0	1
3595	Dec. 9		Raw blocks		6	6	10	0	0
3595	Dec. 13		Roots		3	2	0	0	0
3595	Dec. 20		do		3	3	10	0	0
3595	Dec. 9			Raw blocks	6	6	10	0	0
3595	Dec. 13			Roots	3	1	0	0	0
3595	Dec. 20			do	4	4	10	0	4
3616	Nov. 27	Tubers			8	8	0	0	4
3616	do	Raw blocks			10	10	0	0	0
3616	Dec. 27	Tubers			4	4	2	0	0
3616	Dec. 9		Raw blocks		6	6	10	0	0
3616	Dec. 27		Roots		11	11	10	0	0
3616	Dec. 9			Raw blocks	6	6	10	0	0
3624	Nov. 27	Tubers			10	[a]10	0	0	3
3624	Dec. 1	do			8	8	6	0	4
3624	Dec. 9	Raw blocks			13	9	10	0	0
3624	Dec. 13	Tubers			6	6	4	0	0
3624	Dec. 27		Roots		6	6	10	0	0
3624	do			Roots	7	5	10	0	0
3626	Dec. 28		Roots		3	2	4	0	0
3626	do			Roots	4	4	4	0	0
3627	Dec. 20		Roots		4	4	10	0	4
3627	Dec. 31		do		5	3	0	....	3
3627	Dec. 20			Roots	4	4	10	0	4
3627	Dec. 31			do	5	4	0	....	4
	1916.								
3624	Jan. 6	Tubers			4	[a]4	0	....	0
3627	Jan. 7			Roots	6	6	3	0	3
3627	do		Roots		6	6	4	0	3

[a] All slightly.

OTHER FUNGI ISOLATED AND STUDIED

In storing on the ground a crop such as dasheens it is only natural that a number of saprophytes would be associated with the storage-rot organism. Two species of Fusarium, *F. oxysporum* and *F. caudatum*, were frequently isolated under such conditions. Although preliminary inoculation experiments made by inserting spores and hyphæ of these organisms with a needle or by smearing spores on a cut surface of the tubers in a moist chamber gave negative results, it was still believed that they would produce true storage-rots under the proper conditions. As the writer believed that sufficient moisture was lacking, the tubers, after being dipped in spore suspension in sterile water, were wrapped with wet filter paper and then with oiled paper and placed in a moist chamber. The results were negative. Tubers soaked for one hour in water and then dipped in a spore suspension and wrapped in filter paper and oiled paper remained sound. Again, tubers kept at a temperature of about 12° C. for 10 days, inoculated and manipulated as above, and kept in a moist chamber yielded no result. It was finally concluded from these results, in view of the fact that other organisms readily cause storage-rots under laboratory conditions, that these two fungi were merely saprophytes. A species of Phomopsis isolated from dasheens from the Hawaiian Islands failed to produce a rot under any of the conditions tried. Other fungi isolated a few times but not studied were *Rhizopus nigricans*, *Penicillium* spp., *Pythium debaryanum*, *Fusarium redolens*, and an undetermined species of Fusarium.

A number of inoculations were made with *Diplodia zeae*, *Sphaeropsis malorum*, and a species of Diplodia from salix, none of which produced a rot.

MOISTURE AS A FACTOR IN PRODUCING ROT

It is likely that moisture plays a far greater part in the production of storage-rots than is generally conceded. Ordinarily it might be supposed that the amount of humidity in a moist chamber lined with saturated filter paper would be sufficient to germinate the spores of most fungi. *Fusarium solani* under those conditions would not invade the tissue of dasheens; but if they were sprayed twice a day for one or two days so that the spores would be suspended in a film of water germination and invasion of the tissue would take place before an impenetrable corky layer had formed over the wound. Some root crops have the power to absorb a considerable quantity of water, so that even though water of condensation may be formed on the glass of a moist chamber, the specimen inside is comparatively dry. For example, five tubers of dasheens with a total weight of 558 gm. absorbed 21 gm. of water in 24 hours, or more than 3.7 per cent of their original weight, and ten sweet potatoes from storage with a total weight of 1,539 gm. absorbed 84 gm. in two hours, or nearly 5.5 per cent of their original weight. Both

dasheens and sweet potatoes continue to absorb water for some time, and sweet potatoes will take up as much as 7 to 20 per cent of their weight in 24 hours, depending naturally on how dry they were when immersed. Relatively the greatest absorption takes place during the first two hours; in extreme cases as much as 10 per cent. The rate of absorption drops off at the end of that time, but the curve continues steadily upward thereafter.

Sclerotium rolfsii also requires considerable moisture to start growth, but requires no addition of water to that in the filter paper of a moist chamber after 24 hours. This fungus may have the power after once becoming well established to penetrate the corky layer over a cut surface. Whether this is accomplished by the action of an enzym was not determined.

Diplodia tubericola and the other closely related forms used in these experiments succeed better under exactly the opposite conditions. If the tubers after inoculation were subjected to the environment of the laboratory room, the results were better than if they were kept in a moist chamber. No attempt has been made to determine a cause for this phenomenon. It must be kept in mind that at the outset protection was afforded the spores and hyphæ by inserting them about a fourth of an inch into the tuber and the tissue squeezed together about the wound.

Bacillus carotovorus, like *S. rolfsii* and *F. solani* succeeded better if a film of moisture was sprayed on the cut surface for a day or two following inoculation. As soon, however, as decay set in, no further application was required, except to the filter paper in the bottom of the moist chamber. It should be noted in this connection also that dasheens, turnips, and carrots differ very much in respect to the moisture actually required to stimulate decay. Dasheens are very dry and absorb moisture quickly and must be sprayed several times to start decay. Turnips and carrots, on the other hand, require but little added moisture, decay starting more promptly and progressing more rapidly.

TEMPERATURE AS A FACTOR IN PRODUCING ROT

Temperature and moisture, so far as their relation to storage rots are concerned, are so closely associated that one can hardly be discussed independently of the other.

It is obvious that decay will not occur at a temperature at which the organism will not grow even in the presence of sufficient moisture or in the absence of moisture with the proper temperature.

RESULTS WITH DIPLODIA TUBERICOLA.—A number of dasheens inoculated with *Diplodia tubericola* from sweet potatoes were divided into two lots, one of which was placed in an incubator with a temperature varying from 34° to 35° C. The other lot was placed in an ice box with a temperature ranging from 12.2° to 13.5°. At the higher temperature

(34° to 35°) the tubers were more than half-rotted at the end of nine days, and in four more days all but one were decayed throughout. At the end of 20 days *D. tubericola* was isolated in pure culture from each. At a lower temperature (12.2° to 13.5°) all the tubers but one were perfectly sound at the end of 45 days. One tuber was half-decayed, and yielded *F. culmorum*.

The temperatures at which decay may be brought about by *S. rolfsii*, *F. solani*, and *B. carotovorus* were determined by the use of raw blocks of dasheen. After discarding the blocks contaminated in their preparation, the remainder were divided into two lots, one of which was inoculated with *S. rolfsii* and the other with *F. solani*. Each of these lots was divided into 6 groups of 10 tubers each and placed in different chambers of the Altman thermostat and in the laboratory room, the temperatures of which ranged as follows:

Chamber No.	Range of temperature.	Average temperature.	Chamber No.	Range of temperature.	Average temperature.
	°C.	°C.		°C.	°C.
5	8.2 to 10.0	9.1	Room	22.0 to 24.0	22.4
6	12.0 to 15.0	14.0	18	26.3 to 29.6	28.6
9	17.5 to 19.5	18.4	19	34.5 to 36.0	35.3

RESULTS WITH FUSARIUM SOLANI.—In all the chambers except No. 5 (9.1° C.) growth started in two days. While there was some difference in the general appearance of the growth in the different chambers, there was nothing strikingly characteristic. At the lower temperatures there was a slight reduction of hyphal growth compared with higher temperatures, accompanied by the production of a salmon-orange color on the blocks. At the higher temperatures, particularly in chambers 18 (28.6°) and 19 (35.3°), abundant hyphæ were produced. An accident to chambers 18 and 19 at the end of 10 days terminated that part of the experiment, but an examination of the tubes showed that the blocks were completely decayed and typical spores of the causal organism produced. The others were continued for 20 days longer. At the end of that time no decay had taken place in chamber 5 (9.1°), and no spores were formed, though a slight discoloration of the blocks had taken place. In all the other chambers the blocks were completely softened. In the tubes exposed to room temperature (22.4°) typical spores were produced, while in chamber 6 (14.0°) there were a few abnormal spores, in No. 9 (18.4°) many. In general it may be stated that while decay was complete in all chambers except in No. 5 (9.1°) spore production was better at the three higher temperatures. The results therefore seem to indicate that tubers stored at the higher temperatures are more liable to be decayed by *F. solani* than if stored at a temperature of 8° to 10° or lower.

RESULTS WITH SCLEROTIUM ROLFSII.—This organism produced no decay at the end of 38 days in chamber 5 (9.1° C.), but a few immature sclerotia were formed. In all the other chambers visible growth appeared in two days. In chambers 6 (14.0°) and 9 (18.4°) hyphæ were abundantly produced and the sterile blocks completely decayed, but no sclerotia were produced at the conclusion of the experiments. At the three higher temperatures the blocks were also decayed, but the production of hyphæ was markedly less and the number of sclerotia relatively larger, increasing in number with the increase in temperature. It therefore appears that the minimum temperature at which this organism will produce decay is near 8° to 10°. Other things being eliminated, dasheens would apparently, from the results of these experiments, keep better if stored at a temperature of about 8° to 10°.

RESULTS WITH BACILLUS CAROTOVORUS.—Experiments to determine the range of temperature of *B. carotovorus* were made some months later by inoculating sterile raw blocks of turnips and dasheens. The blocks were inoculated with a 24-hour-old culture of strain 3616 grown in beef bouillon and exposed in a series of chambers of the Altman thermostat and in the laboratory room to the following average temperatures:

Chamber No.	Range of temperature.	Average temperature.	Chamber No.	Range of temperature.	Average temperature.
	°C.	°C.		°C.	°C.
2	3.5 to 5.0	4.0	9	15.7 to 20.0	17.3
3	5.2 to 7.0	6.1	Room	20.0 to 25.0	23.0
5	9.0 to 12.0	10.0	18	29.2 to 36.2	32.7
6	11.0 to 14.8	12.3	19	34.7 to 37.9	35.8
8	14.6 to 18.5	16.0	20	38.0 to 41.6	39.3

The tubes were kept in the chambers for 27 days. At the end of that time no growth had taken place in chamber 2 (4° C.) and but a slight growth in 3 (6.1°), and 20 (39.3°). In six days a slight decay had started in chamber 5 (10°) and in three days in chamber 6 (12.3°). At the end of 14 days the dasheens were completely decayed in chamber 5. The turnips, on the other hand, were only partially decayed at the close of the experiment. In chamber 6 the dasheens were completely decayed at the end of 11 days and the turnips nearly so at the end of 14 days. In all the other chambers decay was noticeable at the end of two days, but progressed more rapidly with the increase of temperature up to and including 18 (32.7°). At the end of 11 days the dasheens were completely decayed in chamber 8 (16°) and the turnips mostly so, while in 9 (17.3°) the dasheens were completely decayed in 7 days and the turnips in 11 days. In chamber 18 (32.7°) both dasheens and turnips were completely decayed in 3 days, while in 19 (35.8) decay was not complete until 10 days. A parallel series of tests was run

in the laboratory room (23°), and decay was completed in 10 days. From these results there is a wide range of temperatures at which decay by this organism will take place. It is apparent, however, that the optimum lies somewhere between 32° to 35° and the minimum at approximately 4°. The maximum temperature was not determined, but in view of the fact that a slight decay of the blocks occurred in chamber 20 (39.3°), it must be somewhat higher.

It is interesting to note in this connection that the dasheens in most of the chambers were more promptly decayed in this experiment than the turnips. In other experiments of a similar nature both in the laboratory room and in the thermostat chambers this has not always been the case. In fact, it has frequently happened that the turnips, and carrots also when they are included in the tests, were more promptly decayed than the dasheens. While a strain (3616) originally obtained from dasheens was used for inoculating the blocks, turnips and carrots inoculated with this strain in moist chambers were generally more speedily decayed than dasheens. While no positive explanation of such a condition will be attempted, it has been apparent throughout the whole course of the work that the condition of the material when used plays no little part in the results to be obtained. It has been noticed that fresh turnips and carrots decay after inoculation more readily than those that have been kept in the ice box or elsewhere under conditions permitting the escape of moisture and eventual withering. Dasheens, on the other hand, lose moisture more slowly and remain suitable for such experiments a much longer time.

SUMMARY

(1) There are four storage rots of economic aroids: Java blackrot caused by *Diplodia tubericola*, *Diplodia maclurae*, *Diplodia gossypina*, and *Diplodia* sp. from *Mangifera indica;* powdery grayrot caused by *Fusarium solani;* sclerotium-rot caused by *Sclerotium rolfsii;* and softrot caused by *Bacillus carotovorus*.

(2) All of the species of Diplodia cause a rot identical in character.

(3) All the causal organisms are wound parasites.

(4) The parasitism of each organism has been established by inoculation experiments.

(5) *F. solani* from the Irish potato produces a rot identical with the rot produced by *F. solani* from the dasheen.

(6) Several other organisms were studied, none of which were found parasitic.

(7) The Java blackrot organism produced decay better under relatively dry conditions.

(8) It was necessary to apply sterile water once or twice to the tubers and corms after inoculation with *F. solani*, *S. rolfsii*, and *B. carotovorus*. After decay had started, no further application of water was required.

(9) High temperatures were more favorable to decay than low temperatures.

(10) *B. carotovorus* alone produced decay at an average temperature below 9° C.

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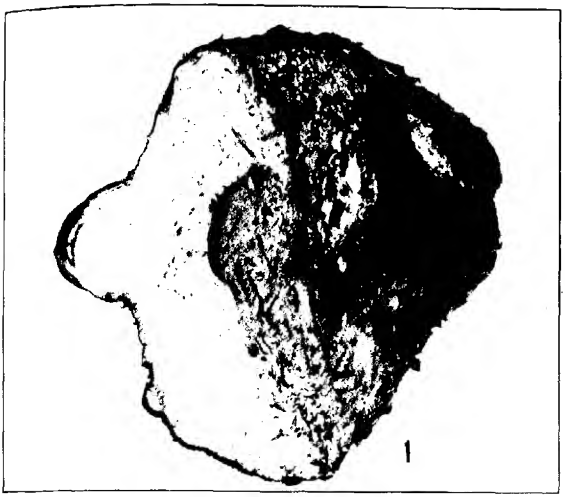
PLATE LXXXI

Fig. 1.—A dasheen corm (*Colocasia esculenta*) showing Java blackrot produced by *Diplodia tubericola*. The blackrot end of the corm is separated from the healthy tissue by a dark brown area which in turn blackens later. Field material from Brooksville, Fla.

Fig. 2.—A corm of *Alocasia sp.* showing Java blackrot produced by *D. tubericola*. From a laboratory inoculation.

Fig. 3.—A dasheen tuber partially decayed by *Sclerotium rolfsii*. From a laboratory inoculation.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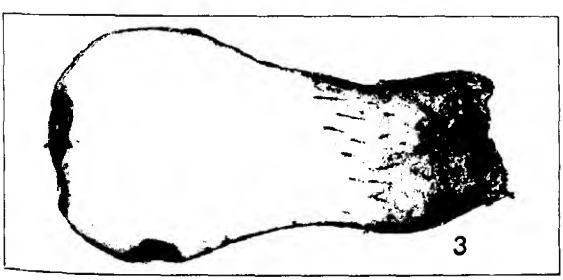
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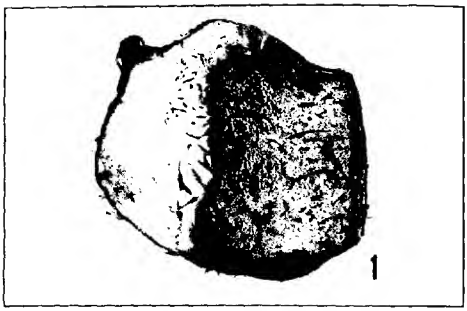
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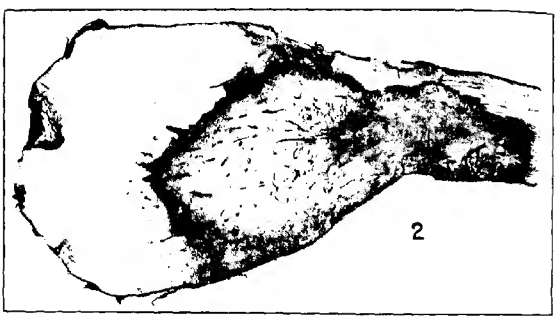
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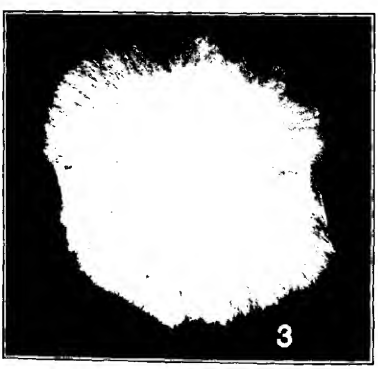
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PLATE LXXXII

Fig. 1.—A tuber of *Colocasia esculenta* showing a powdery grayrot caused by *Fusarium solani*. From a laboratory inoculation.

Fig. 2.—A tuber of *Xanthosoma sagittifolium* showing partial decay by *Fusarium solani*. From a laboratory inoculation.

Fig. 3.—A tuber of *C. esculenta* softened throughout by *Sclerotium rolfsii*. Note the hyphae over the entire surface. From a laboratory inoculation.

PLATE LXXXIII

A corm of *Colocasia esculenta* from Brooksville, Fla., mostly rotted away by *Bacillus carotovorus*. The organism isolated from this corm produced positive laboratory infections.

EXPERIMENTS WITH CLEAN SEED POTATOES ON NEW LAND IN SOUTHERN IDAHO

[PRELIMINARY PAPER]

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It has generally been assumed by plant pathologists that if disease-free potatoes (*Solanum tuberosum*) were planted on new land the resulting product would be free from disease. For the past three years the writer has been engaged in investigations of potato diseases in southern Idaho, where this crop is grown under irrigation. As these irrigated tracts have but recently been opened up, there are many acres of land which may be classed as new in every sense of the word, since no agricultural crops have ever been grown upon them. Pathologists and potato growers alike believed that in these new lands just reclaimed from the desert lay a wonderful opportunity for the production of disease-free potatoes. However, from the beginning of the potato-growing industry in the irrigated portion of southern Idaho potato diseases have appeared each year. It is known that the first seed planted by the potato growers of these irrigated tracts was far from being free from disease, and it was naturally assumed that the diseases which appeared in the product had been introduced with the seed planted. The diseases most prevalent are wilt (*Fusarium oxysporum* Schlect.), blackrot (*F. radicicola* Wollenw.), jelly-end rot (*Fusarium* sp.), Rhizoctonia or russet scab, powdery dryrot (*F. trichothecioides* Wollenw.), and common scab.[1]

During the first two years of the author's investigations of potato diseases in southern Idaho, he observed that when potatoes were planted on virgin land just reclaimed from the desert many diseases usually appeared. Often the product from potatoes planted on such land appeared to be more diseased than that from potatoes planted on land which had been reclaimed from the desert for several years and which had been planted with other crops, such as alfalfa or grain. Frequently when such a diseased crop was observed, the grower would insist that the seed potatoes he had planted had been practically free from disease. Since certain of the diseases found, such as common scab and blackrot, are easily detected on the seed, the writer was forced to admit that in many such cases the grower might be right. Therefore,

[1] No attempt has been made to isolate an organism from the common scab found in this region, but since its appearance is identical with that found in the East it is assumed that the causal organism is the same—namely, *Actinomyces chromogenus* Gasperini.

Journal of Agricultural Research, Dept. of Agriculture, Washington, D. C.

Vol. VI, No. 15
July 10, 1916
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in the spring of 1915, experiments were set up to determine whether a clean product could be obtained by planting disease-free seed on new land. While these experiments are to be continued another year, the results of the first year's trials were so conclusive and of such importance to the potato-growing industry that it appears desirable to record them at the present time.

In the spring of 1915 arrangements were made with several farmers to plant clean seed on lands which had never before been planted to potatoes. The plots planted ranged from one-twentieth of an acre to 1 acre in size. Six of the plots were planted on virgin soil reclaimed from the desert for the express purpose of planting with disease-free seed potatoes. Fourteen of the plots were planted on land which had for several years been in alfalfa or grain. On the grounds of the experiment station at Jerome, Idaho, other plots were planted with disease-free seed.

The land at the experiment station was reclaimed from the desert in 1910, planted to barley, and thereafter to alfalfa.

The varieties planted in the test plots were as follows: Idaho Rural, Netted Gem, Rural New Yorker, Pearl, Peoples, Red Peachblow, Burbank, Carmen No. 3, and Early Six Weeks. The disease-free seed was selected in the same manner for each plot as follows: Each tuber was first carefully examined for all external evidence of disease, such as common scab and the sclerotia of *Rhizoctonia* sp. All tubers showing evidence of either of these diseases were rejected. No tubers showing any large amount of infection with powdery dryrot were used. If there was only a small pocket of dryrot present, the infected portion was cut out until the tissues appeared white and clean. The externally clean tubers were then cut, the first cut being made across the stem end. The stem end portion was invariably discarded. If there was no evidence of vascular or other discoloration, the balance of the tuber was considered free from disease and was cut into pieces averaging about 2 ounces each. After cutting, the tubers were disinfected for 1½ hours in a solution of mercury bichlorid (1:1,000).

Throughout the season each plot was carefully watched, cultures being made from time to time as evidence of disease appeared in the plants. Wilt was found in every plot and *Fusarium oxysporum* was obtained in artificial cultures from stems showing vascular discoloration. Stem lesions and footrots were especially severe in all of the desert (or virgin) land plots. In all of the desert-land plots the plants presented a sickly appearance as compared with the plants in the alfalfa and grain land plots. There were indications in each of the desert-land plots of light yields and of a diseased product.

At harvest time the following methods were employed to determine the diseased condition of the tubers: In each of the smaller plots 100 hills were dug and the product of each hill examined separately. The

tubers were first examined for the presence of external diseases, such as Rhizoctonia or russet scab, common scab, blackrot, and jelly-end rot, after which each tuber was cut to determine the presence or absence of infection in the vascular tissue. The method employed in each of the larger plots was the same as in the smaller ones, except that several lots of 100 hills each were dug in different parts of each plot. All tubers showing pronounced vascular discoloration were considered as infected with wilt caused by *Fusarium* spp. Tubers showing such discoloration were taken to the experiment station laboratory and cultures were made from the discolored vascular tissue. Eighty per cent of all such cultures showed the presence of either *F. oxysporum* or *F. radicicola*. The percentage of vascular infection present in the harvested product was estimated on this basis.

The average percentage of disease present in the alfalfa-grain land plots, planted with disease-free seed, including the plots at the Jerome experiment station, was as follows: Common scab, 4.7 per cent; Rhizoctonia or russet scab, less than 2.8 per cent; vascular infection, 26 per cent; and fieldrots caused by *Fusarium* spp., less than ½ of 1 per cent. In the desert-land plots the averages were as follows: Common scab, 9.3 per cent; Rhizoctonia or russet scab, 11.6 per cent; vascular infection, 29.3 per cent; and fieldrots caused by *Fusarium* spp., 5.6 per cent. The fieldrots caused by species of Fusarium are blackrot (*F. radicicola*) and jelly-end rot, the causal organism of which has not been definitely determined, but with it are associated *F. radicicola* and *F. oxysporum*, as well as other species of Fusarium. Of these two fieldrots, blackrot was the one principally found. Jelly-end rot was confined to the Netted Gems and rarely occurred.

It will be seen that the percentage of disease was much higher in the plots planted on virgin soil than in the plots planted on land which had previously been cropped with alfalfa or grain. When the fact is taken into consideration that the yield in each of the desert-land plots was light and the tubers small and of poor quality, it must be admitted that raw desert lands are not well adapted to the production of high-grade seed stock.

From the results so far obtained from the experiments the following conclusions are drawn:

(1) Planting clean seed potatoes on new land does not guarantee a disease-free product.

(2) A smaller percentage of disease may appear in the product when clean seed is planted on alfalfa or grain land than when similar seed is planted on virgin or raw desert land.

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